Coronagraph for AFTA

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Charge:

Use of the 2.4m telescope asset to advance the science of WFIRST (study includes an optional second instrument to advance exoplanet science).

Why examine additional coronagraph?

- Complementary field of view
- Additional volume can accommodate narrow field instrument
- High quality wavefront and potential telescope stability
- Can work with either orbit being considered
- Leverage WFIRST mission to advance exoplanet imaging

Outstanding opportunity for exoplanet science and technology pathfinding that would enable a future mission. Coronagraphs exist that could be made flight ready almost immediately.

Ultimate performance dependent on stability and thermal properties of telescope.

General Approach:

- Design a proof-of-principle coronagraph that works with AFTA pupil with conservative performance and corresponding science.
- Explore "aggressive" coronagraphs that can significantly enhance science but with lower TRL and higher risk.
- Develop strawman instrument design (imager + spectrograph) compatible with WFIRST instruments.

As has been discussed about WFIRST, we are not designing final mission, just determining that coronagraph science is possible and compelling.

Conservative assumptions:

- 3 to 3.5 lambda/D inner working angle
- 10^{-8} to 10^{-9} raw contrast
- 20 to 30% throughput
- 10 to 20% bandwidth (single channel)
- 400 to 1000 nm

Aggressive possibilities:

- 1.5 to 2 lambda/D inner working angle
- 10^{-9} to 10^{-10} raw contrast
- 60 to 80% throughput
- 10 to 20% bandwidth (single channel)
- 400 to 1000 nm

Aggressive designs are typically more chromatic, more complex, and more sensitive to low order aberrations.

Conservative High-Contrast Science:

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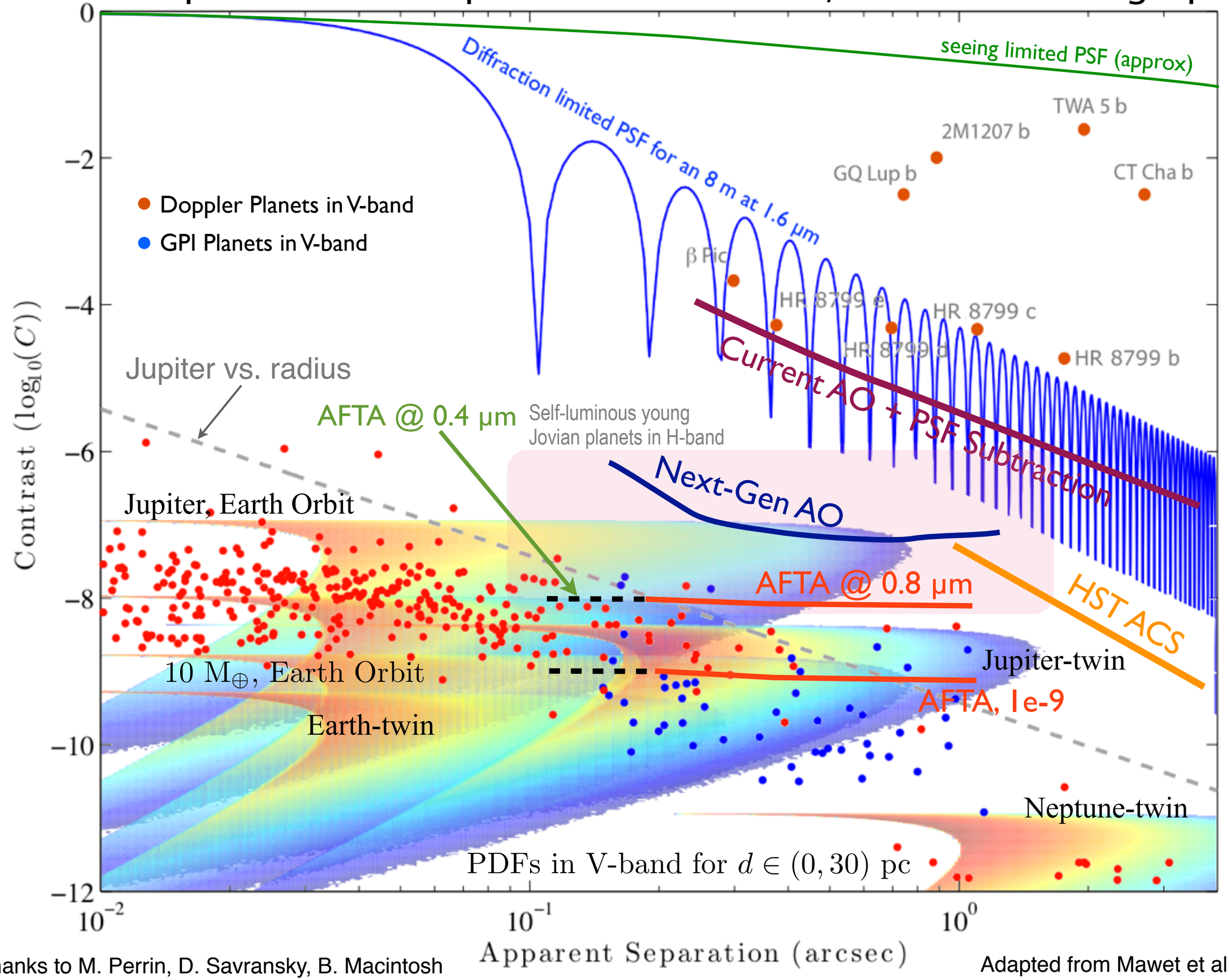
- Protoplanetary and debris disk imaging
  1. Evolution of disk structure down to 1 AU = constraints on planet formation
  2. Disk multi-color imaging & polarimetry = dust properties
  3. Debris disk structure characterization = indicators of planets
  4. Exozodi dust measurements in visible down to a few local zodi at 1 AU = prepare for terrestrial planet direct imaging
- Gas and ice giant exoplanet detection & characterization
  1. Visible colors of some RV and GPI/SPHERE planets
  2. Optical spectra of brightest detected planets = comparative planetology
  3. Discovery of reflected light Jupiters and Neptunes from 0.1 to 1 arcsec

Exoplanet Search Space with 3 lambda/D AFTA Coronagraph



Thanks to M. Perrin, D. Savransky, B. Macintosh

Adapted from Mawet et al. 2012

Additional "stretch" science with aggressive coronagraph:

- Higher resolution zodi characterization out to 5 or 10 AU
- Close in ice giants
- Super-Earths and Earths in habitable zone around several close stars

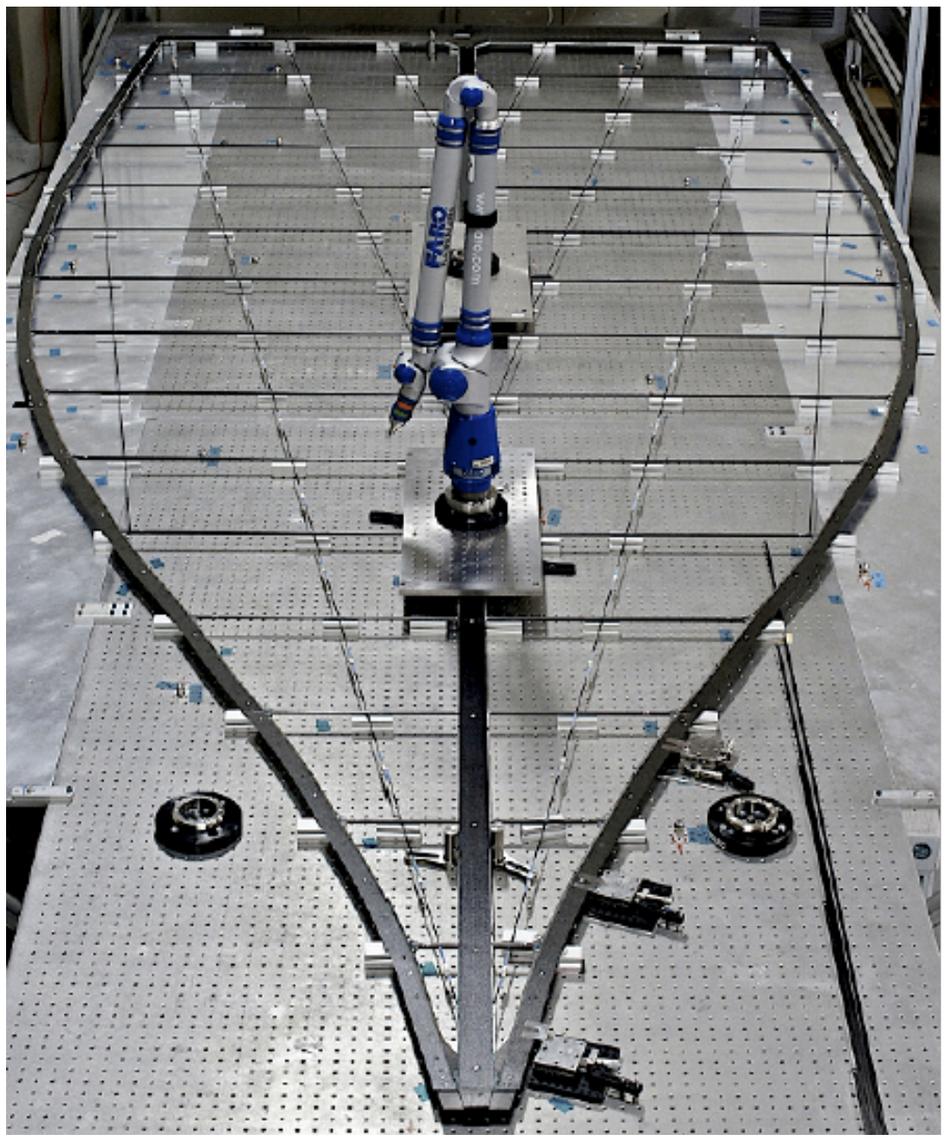
Actual science yield depends upon mission time, integration time, and zodi background. Telescope must be stable for potentially long integrations. A monte-carlo DRM analysis will be started after Thanksgiving.

Potential coronagraph types

- Simple, lower performance
  - Pupil apodization/Shaped Pupils
  - Apodized Pupil Lyot Coronagraph
  - Bandlimited Lyot coronagraph
- More complex and/or less mature
  - PIAA/CMC
  - Complex Lyot
  - Hybrid shaped pupil/4QPM & Vortex
  - Vector Vortex
  - Visible Nulling Coronagraph

Coronagraph must be shown to work with large central obstruction and six non-radial spiders.

Should AFTA-WFIRST go to L2, consider an occulter!



- Contrast and Inner working angle independent of telescope.
- No wavefront control needed, only on-axis camera.
- Could detect Earth's in habitable zone.
- Full band (400-1100) spectroscopy at once.
- Recently completed prototype petal compatible with 10^{-10} mission.

- Requires second spacecraft in addition to narrow-field camera and spectrograph.
- Telescope must be equipped for cooperative sensing and control.

It would be prudent to include the capability on AFTA (RF-link and NIR tracking camera).